



**The Co-Production
of Ethanol and Electricity
From Carbon-based Wastes**

A Report from BRI Energy, Inc.
Regarding a New Technology
That Addresses Multiple Energy
and Waste Disposal Solutions

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THE CO-PRODUCTION OF ETHANOL & ELECTRICITY FROM CARBON-BASED WASTES

Carbon-based wastes represent one of the world's most promising and virtually untapped renewable energy sources. In the United States, more than 1.5 billion tons of municipal solid waste, biosolids, agricultural, forestry and other waste products are generated each year.

During the past 25 years, government and private industry in the United States have spent some \$9 billion attempting to develop economic and environmentally sound methods for the production of electricity and liquid energy from these resources.

Despite this effort, less than 3% of America's liquid fuel and electricity currently comes from biomass and even less is generated from organic waste. Coal-fired power plants, on the other hand, represent the nation's largest single source of industrial air pollution.

According to the Department of Energy, the United States in 2005 imported 65% of its crude oil and petroleum products at a cost of some \$100 billion, severely impacting the nation's balance of payments and its national security. During this same year it is estimated that the nation spent at least \$80 billion more to protect the strategic interests of the petroleum industry in the Mideast.

Global energy demand will increase 54% by 2025, during which time demand for electricity will almost double. Crude oil consumption will increase by 44% from 85 million to 126 million barrels per day and fossil fuels are expected to reach 85% of the world's primary energy mix. America's oil consumption is projected to increase 32% and China's is expected to increase by 119%. By 2025, China will be using about half as much petroleum as the United States.

Increased domestic oil production cannot possibly keep pace with the nation's growing demand for liquid energy, and in this competitive market, with petroleum becoming more difficult to access and bring to market, inflationary pressures on the price of crude oil are destined to continue.

The National Academy of Sciences predicts that hydrogen-powered vehicles won't be readily available for another 25 years, and before that time, the Natural Resources Defense Council estimates that Americans will buy 450 million new cars and trucks.

We live in a petroleum-based economy and this is not going to change any time in the near future. Therefore, America's only solution is to blend an environmentally-safe volume extender with gasoline to reduce the nation's dependence on foreign oil and its cost of liquid energy. Only one substance can achieve this and that is ethanol—and ethanol is already integrated into America's liquid energy distribution system.

Ethanol is already being used around the world in gasoline blends of 10-85%. (For example, 40% of all new cars being sold in Brazil are capable of burning 100% ethanol and all gasoline sold there contains at least 25% ethanol. Brazil will soon be energy independent.) Ethanol improves octane performance. Further, Michael Wang of the Argonne National Laboratory reports that cellulosic ethanol will achieve greenhouse

gas (CO₂) emission reductions of 85% per gallon of ethanol used to displace an energy-equivalent amount of gasoline, even with only 10% blending.

The nation's current ethanol production capacity is 4.1 billion gallons annually, with another 1.5 billion gallons of capacity under construction. However, this is but a fraction of the market potential, because, in the United States, 10% blending, which can be achieved without any modification of existing automobile engines, would require 14 billion gallons.

Ethanol, to date, has been produced chemically from ethylene or biologically from the fermentation of sugars from carbohydrates found in agricultural crops like corn kernels. Sugar fermentation has been the only process to commercially produce ethanol from biomass. However, it is inefficient and until the current escalation in petroleum costs, has not been profitable. The industry has relied heavily on state and federal subsidies, including a 51-cent per gallon federal subsidy and additional incentives ranging from five to 28-cents per gallon in the corn-producing states.

Further, the quantity of ethanol that can be produced from available cropland without impacting America's other uses for corn has been estimated to be 6-8 billion gallons annually, or approximately 4% of the nation's current demand for fuel.

If electricity and ethanol (and for the future, hydrogen) could be produced profitably from America's waste streams, it could help to stabilize the nation's supply of electrical energy, supplement or replace gasoline, convert vast quantities of waste to energy while reducing communities' costs of waste disposal, reduce greenhouse gases and significantly reduce the nation's dependence on foreign oil.

This BRI Renewable Energy Process makes these goals achievable.

The BRI Renewable Energy Process

Combining thermochemical and biochemical technologies, a new gasification/biocatalytic process developed for BRI Energy LLC ("BRI") by a team led by Dr. James L. Gaddy of Fayetteville, Arkansas, makes possible the co-production of electricity and ethanol from any carbon-based materials, including:

- Municipal Solid Waste
- Biosolids & Animal Wastes
- Green Waste
- Agricultural residues
- Used Tires & Plastics
- Timber and Wood Wastes
- Coal, natural gas and other hydrocarbons
- Refinery Tars & Waste Oils

Efficient and economically viable, the BRI process utilizes an enzyme from a patented bacterial culture that ingests synthesis gas (thermally decomposed wastes) to produce fuel-grade ethanol, yielding up to 85 gallons per dry ton of biomass. From high BTU content materials like plastics, used tires or hydrocarbons, it can yield 150 gallons or more per ton.

Unlike combustion, the technology uses an enclosed two-stage thermal process (either gasification or plasma arc) to decompose organic materials into their basic gaseous elements at temperatures of up to 2,350°F.

Before being introduced to the patented bacterial culture in the bioreactor, the synthesis gases (CO, H₂ and CO₂) are scrubbed, put through active carbon filtration and cooled to approximately 98°F—a process that generates an enormous amount of waste heat that can be used to create high temperature steam to drive electric turbines.

In the biocatalytic step, the bacteria ingest the syngas and emit ethanol and water, which is then distilled away to produce 99.5% pure industrial or fuel-grade ethanol. Contrary to current sugar fermentation technologies, the process is odorless.

As the process uses waste products that otherwise would have been placed in landfills and BRI's plants will generate an excess of electricity beyond their parasitic needs, they can produce liquid and electric energy while consuming zero new BTUs in the process. This makes the current discourse about the energy efficiency of ethanol obsolete.

The bacterial culture is anaerobic and dies when exposed to air. The process creates no environmental or health hazards, ground or water contamination, and minimal air emissions. When biomass is used to co-produce ethanol and electricity, significant reductions in greenhouse gas emissions can be achieved.

The BRI process will gasify any carbon-based material whose moisture content is less than 40% (by weight). Its feedstocks need not be chipped, shredded or sorted to remove metal and glass, and they can be blended. Any mixture of MSW, plastics, tires, animal wastes, paper or yard wastes, construction debris, hazardous wastes, crop residues, timber slash, etc., can be converted into synthesis gas, and then to ethanol.

BRI's plants will also operate on natural gas, petroleum and coal--and these hydrocarbons can be blended with biomass to increase by up to 100% the overall gallon-per-ton output of a plant. Gasification eliminates the need to combust coal in the generation of electricity, removing a major source of industrial pollution. The technology can reform landfill methane into ethanol.

The process will normally convert more than 90% of the waste it receives. The residue, a non-hazardous ash, is discharged from the gasifier and can be recycled in products like cement blocks or paving. The net effect is that the BRI process can extend by up to 80% the effective life of a landfill (and it can reclaim and convert into productive energy materials already residing in landfills).

The entire process, from the time the waste material enters the gasifier to the creation of ethanol, takes approximately seven minutes. Current biomass ethanol technologies that use corn kernels or sugar cane as their feedstocks require 36-48 hours for sugar fermentation alone.

This is one of the great strengths of the BRI technology, because this rapid biochemical conversion, plus the fact that the process creates up to five revenue sources, makes the technology profitable and competitive with gasoline, even if ethanol subsidies were to be phased out.

If and when fuel cells become available to power automobiles, the BRI process can also be used to create hydrogen.

A Typical BRI Renewable Energy Plant

BRI's plants will be modular, and by adding modules, their capacities can be readily expanded. A single module will combine two complete energy production lines, each with a capacity to process 125 to 150 tons of waste per day. They will utilize either gasification or plasma arc technologies. Each module will process up to 100,000 tons of biomass annually, and depending upon the BTU content of the feedstock, will produce approximately 6-8 million gallons of ethanol and generate 5-6 MW of power. The amount of ethanol and electricity to be produced by any module can be varied according to energy demand.

Among other configurations, a mid-sized BRI Renewable Energy Plant would employ seven modules to produce approximately 50 million gallons of ethanol and generate approximately 35 MW of power (about 21 MW being surplus to plant operations). It would process 700,000 tons of municipal solid waste, waste tires and/or wood wastes per year.

The combination of electrical generation and low-priced ethanol production (even if federal subsidies were to be phased out) makes possible long-term firm and stable contracts for the generation and sale of "green power" at between five and ten cents per kWh. On the ethanol side, current feedstock costs for corn kernel-based sugar fermentation technologies are approximately \$.80 per gallon. (This assumes a current corn price of \$2.25 per bushel. A bushel of corn will produce 2.8 gallons of ethanol.) Conversely, municipalities will pay BRI Energy to dispose of their wastes, rather than landfill them. Assuming a tipping fee of \$18 per ton, the BRI plant will realize a negative feedstock cost of about \$.25, in total a \$1.05 per gallon advantage over current ethanol production technologies.

Status of Technology

It has been 17 years since the first bacterial culture to convert synthesis gas into ethanol was isolated by Dr. James L. Gaddy and his technologists at BioEngineering Resources, Inc., in Fayetteville, Arkansas. After a long and patient technology development process, some 50 patents have now been awarded or are pending worldwide for the microorganisms, process and methods.

Since November, 2003, when BRI added a prototype Consutech gasifier, the pilot plant has been operating the complete ethanol production cycle, from waste gasification through the delivery of ethanol, in a single integrated process. Approximately \$15 million in investment, DOE grants and internally generated funds have supported the technology's development.

Katzen International, a Cincinnati-based engineering firm that is renowned for the efficiency of their ethanol separation and distillation technologies, has been closely involved with the BRI process during its entire pilot plant phase. Katzen has designed some 75 ethanol plants around the world. Their technology and expertise will be utilized

to extract commercial grade ethanol from the fermentation tanks. Katzen will be responsible for the process design for BRI's plants.

Under contract to BRI Energy, Parsons Corporation, one of the world's leading engineering firms, has delivered its final Technology Evaluation Report and emissions studies on the BRI process. These will enable BRI to complete the permitting of its initial commercial plants. BRI's first commercial facilities are expected to commence operations in 2007. These plants will consume municipal solid waste, green waste and auto shredding residues among their feedstocks.

America's Waste Resources

More than 1.5 billion tons of municipal solid waste, green waste, sewage sludge, plastics, auto fluff, used tires, agricultural, forestry and other waste products are generated in the United States each year, 320 million tons of which are *readily available* for use in the production of liquid and electric energy.

In addition, America has a three hundred year supply of coal, the combustion of which represents one of its most destructive sources of industrial pollution. Millions of dollars are being spent to develop coal gasification projects, but these technologies must still combust the resulting syngas to generate electricity. The BRI Renewable Energy Process can create electricity without combustion.

It is the only technology that can utilize all of the resources described above as feedstocks—and it is the only technology that can simultaneously produce renewable liquid energy, green power and other products from organic wastes.

Utilizing these waste streams, the BRI process could turn states like New York and California into net exporters, rather than importers, of ethanol. In 2005, California consumed approximately one billion gallons of ethanol, only 8 million gallons of which were locally produced. 40 million tons of post-recycled organic waste are placed in landfills in California each year, enough to produce more than two billion gallons of ethanol and approximately 2,250 MW of power.

In summary, there is enough *readily available* municipal waste in America to produce at least 18 billion gallons of ethanol. Taking into consideration the other sources of waste and domestically-producible fuels that are available, the nation has enough resources to become energy self-sufficient.

The complete development of the Alaskan National Wildlife Reserve would provide only two percent of America's liquid energy needs. It is possible to project that the BRI process could deliver 10% of America's liquid energy requirements from locally-generated waste streams within ten years.

The concept that today's waste streams can become tomorrow's liquid and electric energy supersedes all other solutions in our quest for energy independence.

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